A FEM-based model to study the behaviour of corroded RC beams shear-repaired by NSM CFRP rods technique

PhD candidate

Belal **A**LMASSRI (1)

Supervision

Associate Professor

Firas **A**L MAHMOUD (2)

Full Professor

Raoul **F**RANCOIS (1)

(1) University of Toulouse; UPS, INSA, LMDC, Toulouse, France

(2) Institut Jean Lamour, UMR 7198, CNRS, University of Lorraine, Nancy, France

Lmdc toulouse

INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES TOULOUSE

Université de Toulouse

Section 1
Section 2
Section 3
Section 4
Section 5

Introduction

- General Introduction
- Research Objectives
- Experimental Context
- Experimental Procedure

Section 1
Section 2
Section 3
Section 4
Section 5

Main Experimental Results

- Corrosion Results
- Ultimate Load Capacity
- Failure Modes

Section 1
Section 2
Section 3
Section 4
Section 5

FE Numerical Model

- Concrete Properties
- Steel and CFRP bars Properties
- Modelling of Corroded RC Beams

Section 1
Section 2
Section 3
Section 4
Section 5

FE Numerical Modelling Results

- Load-Deflection Curves
- Failure Modes (Crack Patterns)
- FEM Vs Experimental results

Section 1
Section 2
Section 3
Section 4
Section 5

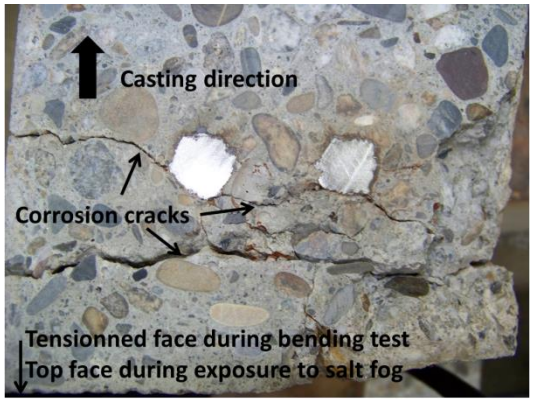
Conclusions

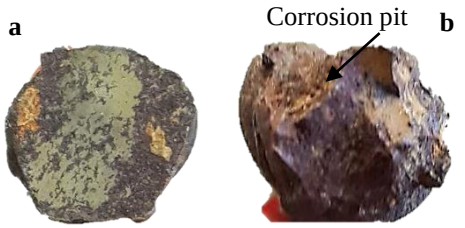
- Conclusions
- Perspectives

General Introduction

Corrosion Effect on RC structures

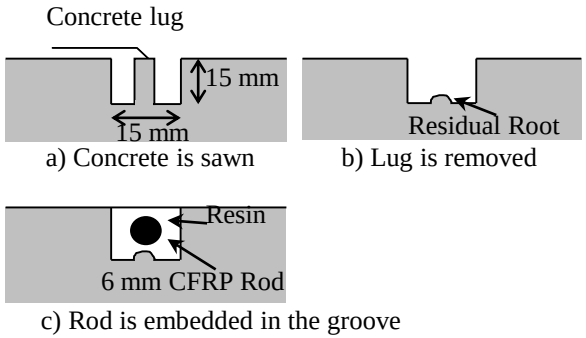
- A reduction in the cross-sectional area of the steel bars.
- Cracking and bonding problems.
- Bending stiffness and load capacity problems.

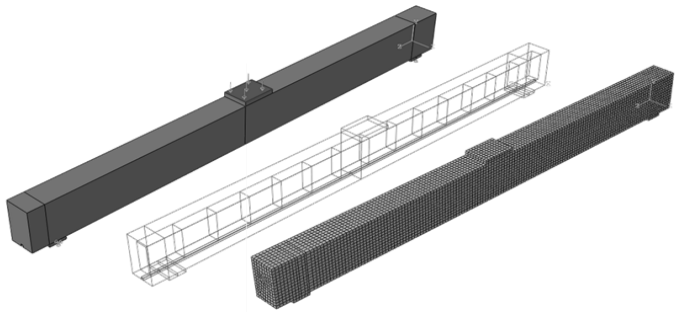




General Introduction

- ✓ Fixing the CFRP rods, by means of a high performance epoxy adhesive, into thin grooves cut onto the concrete cover of the RC beams' lateral faces.
- ✓ Few studies conducted on the predictive performance of computer programs based on the finite element method (FEM) for corroded structures.





Research problem

- ✓ Very few studies presented the effect of corrosion on the shear capacity of such structures.
- ✓ Most of the available literature studied the effect of corrosion on the shear behaviour of RC beams based on impressed current.
- ✓ There are no numerical modelling studies available that were performed to investigate the mechanical behaviour and failure modes of corroded RC beams repaired in shear with NSM CFRP rods.

Research Objectives

Experimental **R**esults

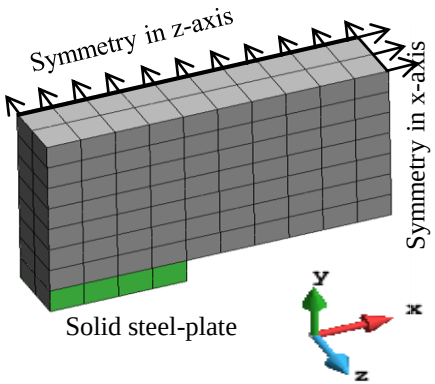
- Three points loading tests
- Corrosion results

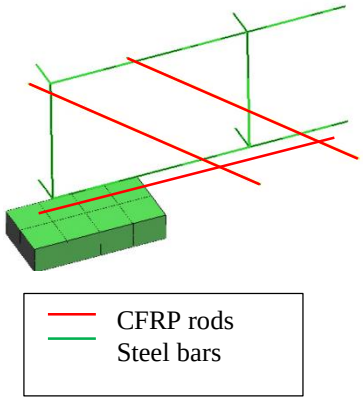
FE Model

- FEMIX computer code
- 3D Non-linear Analysis

Analysis

Experimental Vs FEM



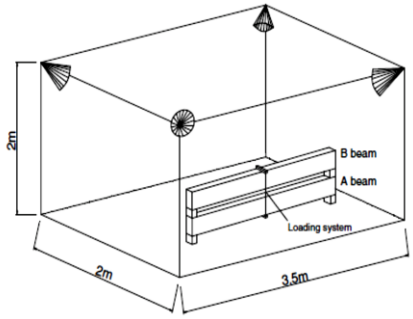


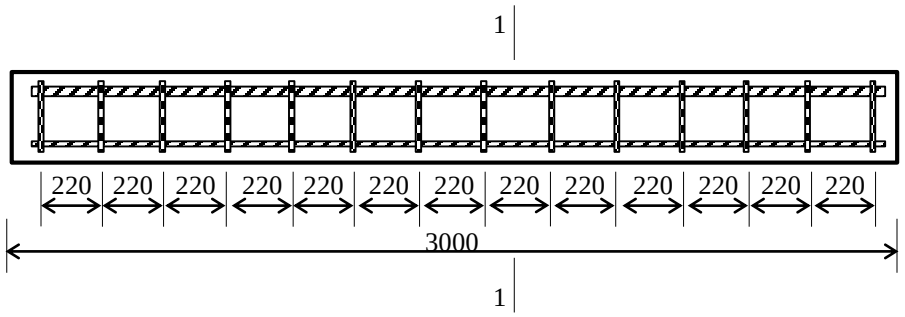
Experimental context

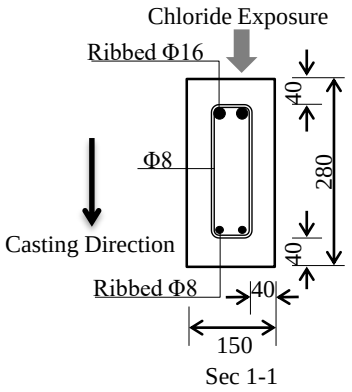
An experimental program was started at LMDC in 1984

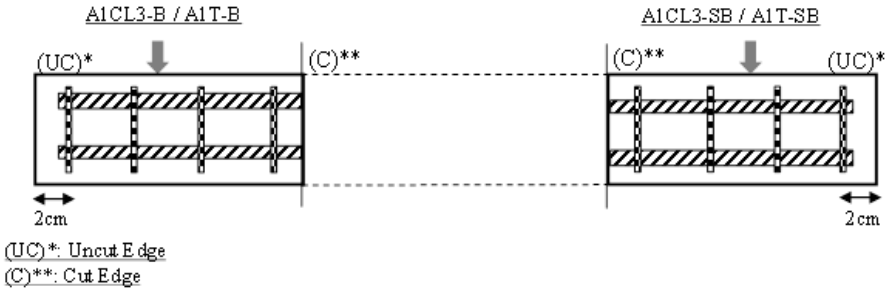
In 2012:

- Two full beams were repaired with NSM in bending.
- The four 80 cm edges were cut of the two long beams.



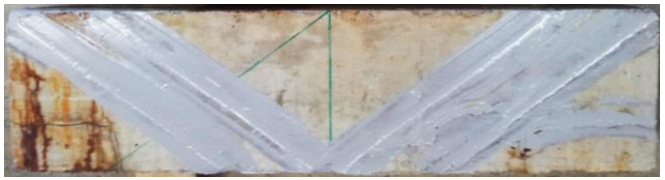


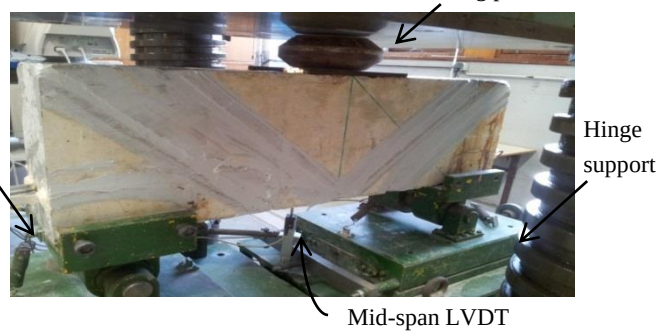




Experimental procedure

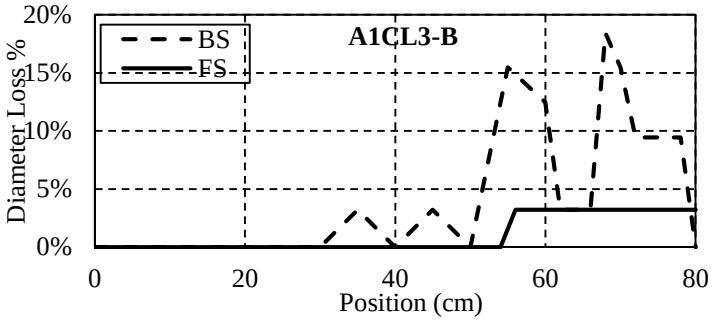
- NSM repair in shear for one corroded short beam (A1CL3-SB) and one control beam (A1T-SB).
- The four beams tested in 3-points loading tests.

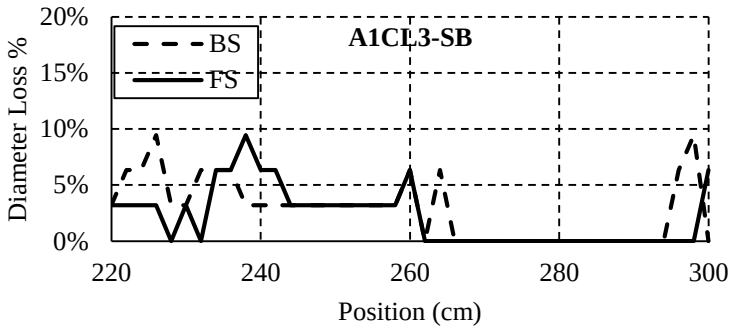


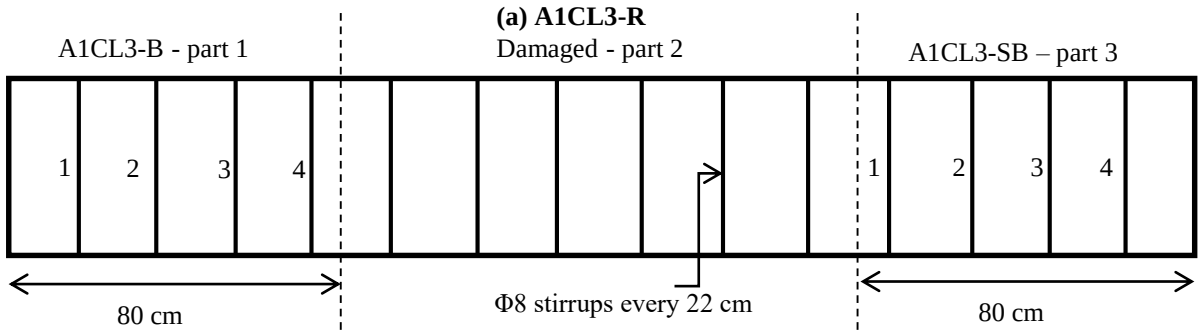


Corrosion Results

- The maximum diameter loss found in the tensile steel bars of beam A1CL3-B was 18% while. for A1CL3-SB. it was 9%.

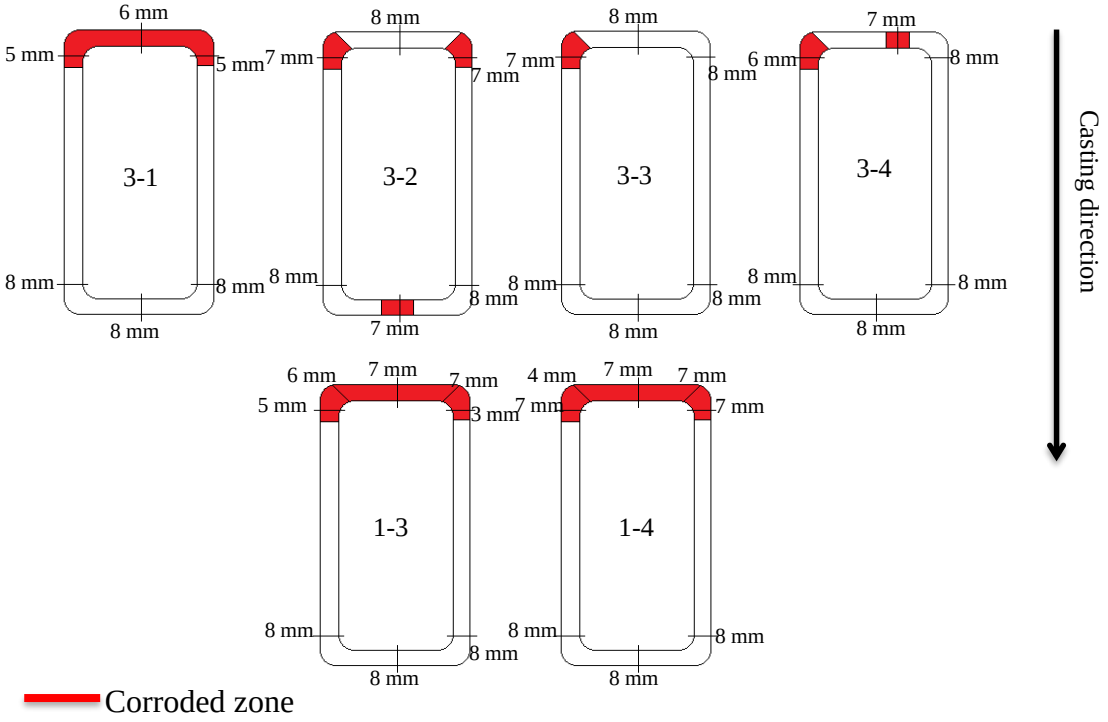






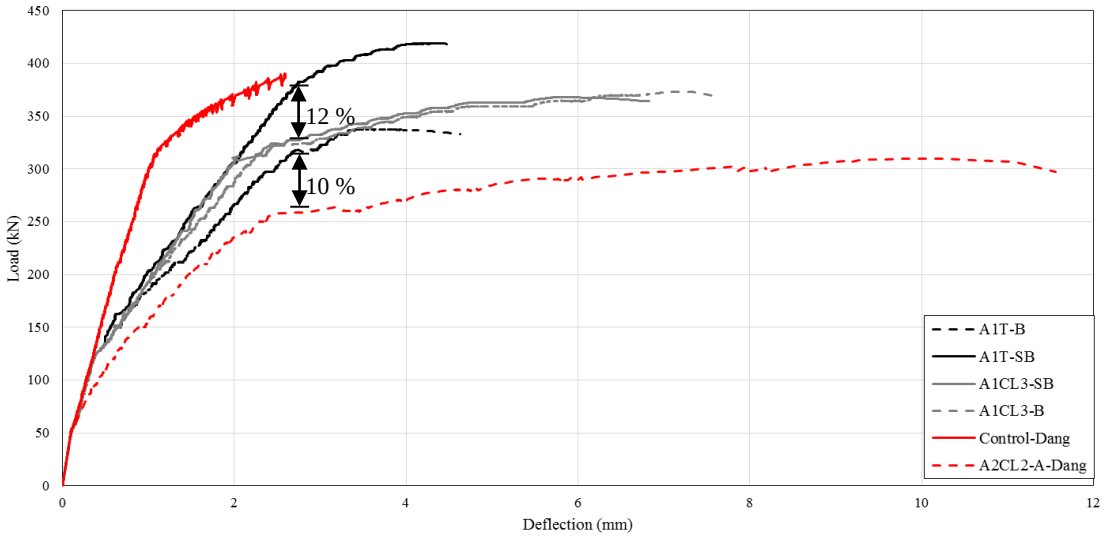
Corrosion Results

- The maximum diameter loss found in beam A1CL3-B was 63 % at stirrup 1-4 (at the far edge of the diagonal shear crack) while the maximum loss in A1CL3-SB was 38 % at stirrup.



Ultimate Load Capacity

- Shear capacity increase of the control beams due to NSM.
- For corroded beams, It depends on the pattern and the intensity of steel corrosion.



Failure Modes

- Diagonal crack failure Vs failure by a large flexural crack at mid span followed by concrete crushing.

a. A1CL3-B

b. A1T-B

Diagonal tension failure (Shear cracking failure with slipping of tensile steel bars)

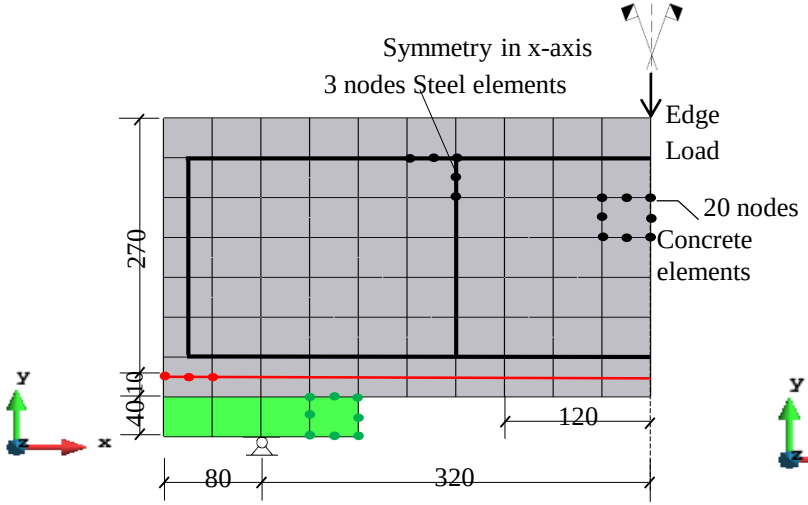
c. A1CL3-SB

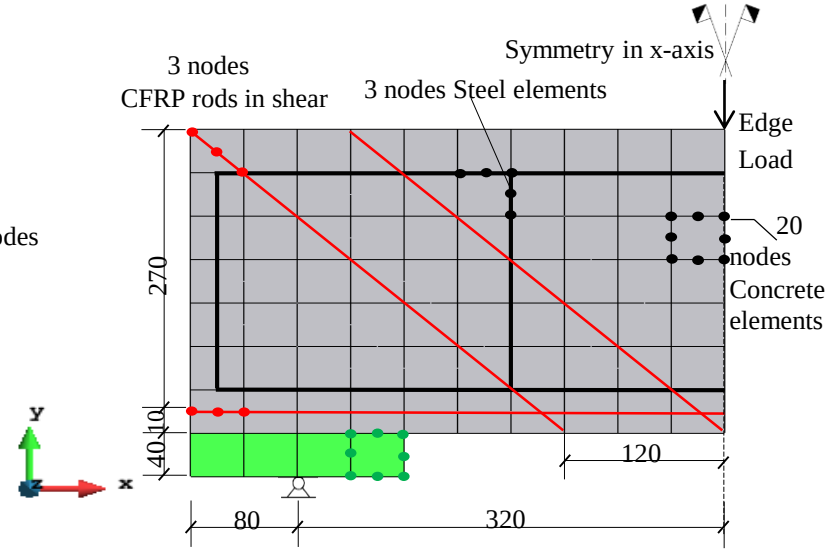
d. A1T-SB

Compression crushing of the concrete (Large flexural crack in the middle of the beam)

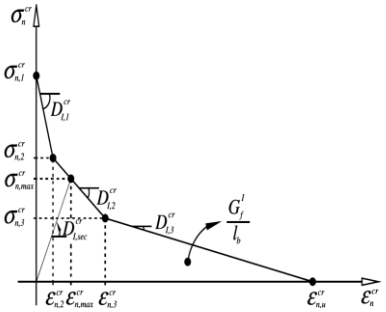
A FEM-based model to study the behaviour of corroded RC beams shear-repaired by NSM CFRP rods technique | FE Numerical Model

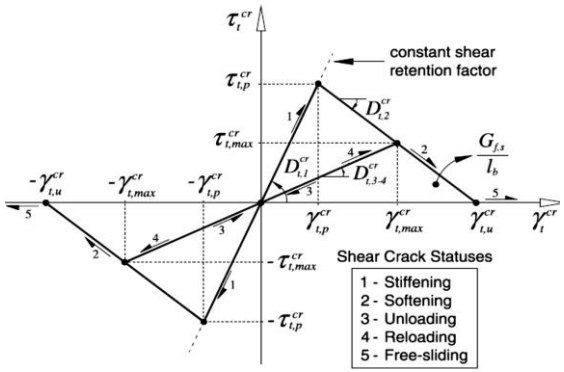
Concrete Properties





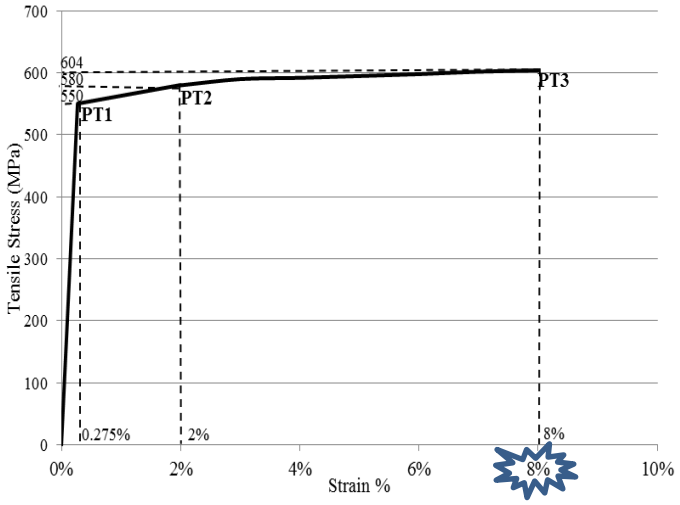
- Fracture mode I : “a tri-linear tension softening or stiffening diagram”.
- Fracture mode II: “shear softening of concrete”.

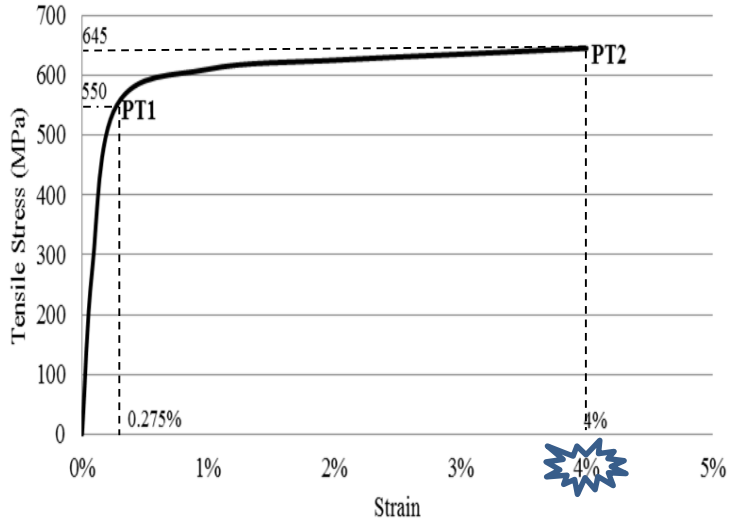




Steel and CFRP Properties

- The steel reinforcement bars were implemented in this model as elastic-plastic behaviour.
- Decreased ultimate elongation for the corroded steel bars and stirrups.

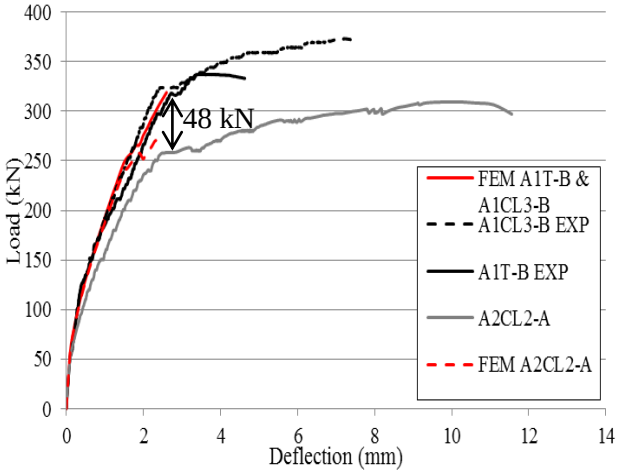


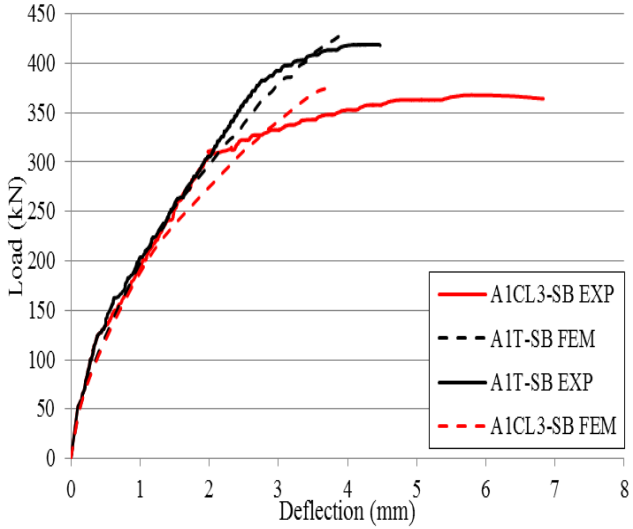


- To model the NSM CFRP rods, a linear elastic stress–strain relationship was implemented.

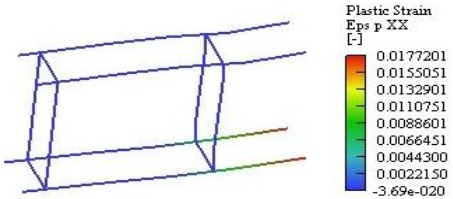
Load-Deflection Curves

- 10% loss of tensile steel bar cross section and 77% of diameter loss were used.
- 12% of loss of cross section led to 12% loss in yielding capacity for SB beams.



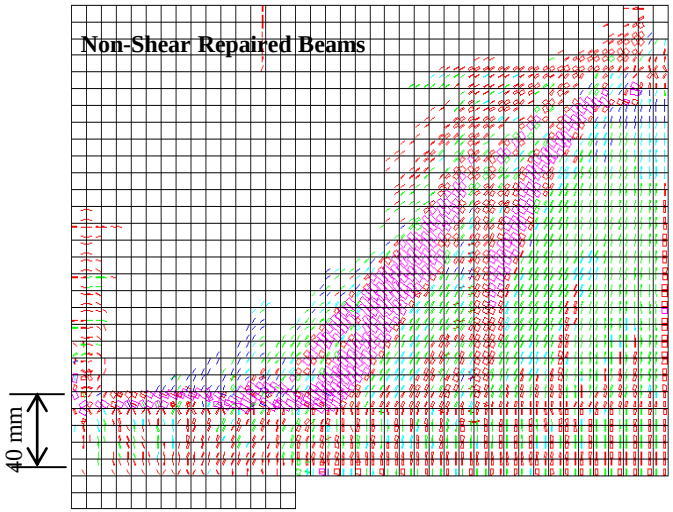


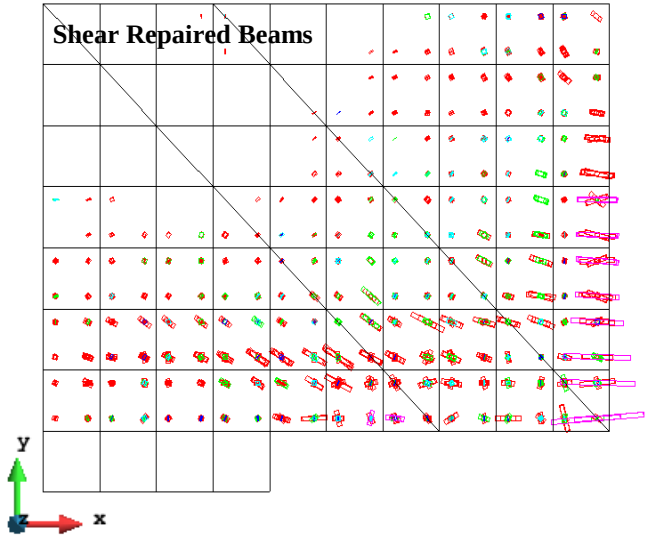
- The steel corrosion did not lead to brittle failure of the steel bars.



Failure Modes

- Diagonal tension failure with large shear cracks for non-shear-repaired beams.
- Large Flexural cracks followed by concrete crushing for shear-repaired beams.





Conclusions & Perspectives

- The FE numerical predictions and the experimental results showed a satisfactory level of accuracy of the proposed model in terms of capturing the load-deflection curves and the crack patterns.
- The loss of cross section of steel bars was well captured by the FE numerical models, which reproduced the same reduction of the yielding capacity as found experimentally.
- A FE numerical model taking account of both the interaction between the NSM CFRP rods and the concrete, and the bond-slip relationship between concrete and corroded steel bars is required in the future.

Questions are never indiscreet,
answers sometimes are.

Oscar Wilde

b.m.88@hotmail.com
almassri@etud.insa-toulouse.fr
Belal Almassri